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SORGHUM CULTIVATION AND SOIL FERTILITY PRESERVATION UNDER *BUJIMI* SLASH-AND-BURN CULTIVATION IN NORTHWESTERN ZAMBIA

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ABSTRACT Here, we describe the cropping system of *bujimi* slash-and-burn cultivation by the Kaonde people in northwestern Zambia. *Bujimi* cultivation comprises three cropping systems: *monde*, making ash patches; *milala*, making mounds; and *masengele*, making flat fields. The three cropping systems accumulate soil fertility in different manners, and soil fertility dynamics vary after cultivation. Sorghum was sown for three or four consecutive years, usually followed by maize cultivation for additional 3 or 4 years. After clearing closed forest, the Kaonde gradually expanded small plots of the three cropping systems in the newly generated grassland adjacent to the cultivated field each year, thus creating new soil in *bujimi* fields for three or four successive years. As a result, varied soil fertility was created in mosaic patterns by combining the cropping systems with the number of cultivation years. The Kaonde also observed the grass species and grass biomass in crop fields and used them as indicators of soil fertility. When they noticed a decline in soil fertility, they planted sweet potato and cassava instead of sorghum monoculture. The Kaonde people maintain sustainable food production through multifold soil fertility preservation and mixed cropping.

Key Words: *Bujimi* system; Kaonde; *Miombo* woodland; Shifting cultivation; Zambia.

INTRODUCTION

The agricultural systems of the Northern Plateau ethnic groups of Zambia are based upon *citemene* methods of clearing forest and preparing the land with ash patches (Trapnell, 1957; Allan, 1965). Trapnell (1957) described three *citemene* types of slash-and-burn agriculture: the large circle *citemene* of the Bemba people, the small circle *citemene* of the Lala people, and the block *citemene* of the Lamba and Kaonde peoples. These ethnic groups are all matrilineal societies, and their territory belongs to the matrilineal zone of central Africa, from Angola to Mozambique through Zambia and Malawi. The Bemba, Lala, and Kaonde call their ethnic groups by themselves and are understood as such by many other people. Bemba and Kaonde are public languages in the Republic of Zambia. The Lala language is regarded as a dialect of the Bemba language in Zambia. The Kaonde and Bemba languages have 80% agreement of basic words (Lehmann, 1978).

According to the classification of Murdock (1959), these ethnic groups form the Central Bantu Cluster and can trace their origin to the Luba Empire, which was situated in the northeastern part of Katanga in the modern-day Democratic Republic of Congo (Jaeger, 1971; Roberts, 1976). The Luba kingdom was formed at the basin of the Lualaba River, in the southern part of the modern Republic of Congo, and is estimated to have been founded in the 15th century or beginning of the 16th century. The Luba people used copper and iron ore, which were abundant in their territory, and engaged in salt making. One major group migrated eastward from Luba territory in the 16th century and established the Bemba kingdom at Kasama, the modern headquarters of the Northern Province, in the mid-17th century. The structure of the Bemba kingdom was centralization of power with a paramount chief of Citimukulu. Small clan-based groups marched south from Luba territory to the area of the modern Northwestern Province. The cluster of groups called themselves "Kaonde." Kaonde society is a loose and flexible system, which bears no relationship to an overall political organization and has no paramount chief or any other central power. Neither do the Kaonde have any specific royal clan from which chiefs are selected (Chibanza, 1961; Jaeger, 1971).

Luba-originated ethnic groups such as Lala, Bemba, Kaonde, and Lamba maintain their own types of slash-and-burn cultivation in the ecological zone of *miombo* woodland. Many reports focus on the large circle *citemene* agriculture of the Bemba people (e.g., Richards, 1939; Kakeya & Sugiyama, 1985; Araki, 1993; Moore & Vaughan, 1994; Oyama, 1996, 2001; Oyama & Takamura, 2001). In contrast, few reports have described the block *citemene* of the Kaonde people (Trapnell, 1957; Allan, 1965; Melland, 1967; Jaeger, 1981).

For rural development and national food security in Zambia, maize cultivation was introduced in the 1970s. The Zambian government and the British Integrated Rural Development Program (IRDP) began the distribution of hybrid seed and chemical fertilizer to villages in the Mufumbwe District in 1978. Socio-economic conditions were favorable for maize production and the Kaonde people adopted maize faming. The agricultural inputs continued until 1987 under IRDP and the Northwestern Province Cooperative Union. In the 1980s, IRDP purchased maize for a favorable price through the main agricultural service center of Kabompo, headquarters of Kabompo District, and maize was the main cash resource for farmers. As Jaeger (1981) reported for the resettlement schemes in Kasempa District, the government launched a resettlement scheme in Kikonge Ward in 1987 to increase agricultural production and concentrate the population around the agricultural service center.

However, the agricultural supply stopped in the province because of government budget depletion in late 1980s and policy changes from government control to market initiatives in the early 1990s. The functions of the agricultural service center not well coordinated, and schemes were rarely operated by the National Service until 1990. The fields for maize and agricultural service facilities were abandoned in 2002.

It is difficult for farmers in remote areas to obtain agricultural inputs such as chemical fertilizers and hybrid maize seed through the market. In the Northern Province, the Bemba people returned to the indigenous *citemene* farming system for subsistence in 1995 (Kakeya et al., 2006). It is necessary to consider the future of farming systems in remote areas of the country to increase food production based on indigenous techniques without agricultural inputs from the exterior market. The potential for indigenous agriculture generated by the natural environment, ethno-culture, and local technology needs to be clarified before introducing new technologies and agricultural inputs from outside. Here, we describe the block *citemene* agricultural system of the Kaonde people and characteristics of the slash-and-burn cultivation observed using participatory research and soil analysis for use in future action research.

RESEARCH AREA

I. Physical Environment

The *miombo* woodland is located in the southern and eastern parts of the tropical rain forest of the Congo Basin. Annual rainfall in this ecological zone varies from 700 to 1,500 mm, and the average temperature is 18 to 24ºC. The research area belongs to the Northern Plateau, at an elevation between 900 and 1,300 m. The rainy season occurs from November to April. The dry season is divided into two sub seasons: the cold dry season from May to the beginning of August and the hot dry season from mid-August to October.

The elevation of the research area is 1,250 m, and the soil is classified as red clay (Jaeger, 1981). The agricultural potential of this area is estimated to be high in the Northwestern Province. The dominant trees in the *miombo* woodland are Caesalpinioideae (*Brachystegia* and *Isoberlinia*), Papilionoideae (*Pterocarpus*), and Mimosoideae (*Acacia*), with a canopy 10–15 m high. According to Trapnell (1957), the vegetation of the research area is northern *Brachystegia* woodland on clay plateau soils of the Northern Plateau type. The country is densely covered with forest, almost entirely infested with tsetse fly, and was regarded as lacking agricultural or pastoral prospects by Europeans before the independence of Zambia. The forest floor is covered with grass species such as *Hyparrhenia* and *Eleusine*. The grasses are 1.0 m high under the forest canopy, and bush fire extends to the ground during the dry season. Along the rivers meandering through the woodland are found seasonal marshes called *dambo*.

II. Kimankata Village

The Kaonde people live mainly in the Solwezi, Kasempa, Mufumbwe, Mwinilunga, and Mumbwa Districts of the Northwestern Province. The research site was Kimankata Village, Kikonge Ward, Mufumbwe District (Fig. 1). Kikonge Ward is located within a territory of Chief Chizela, 1 of 13 chiefs in Kaonde society.

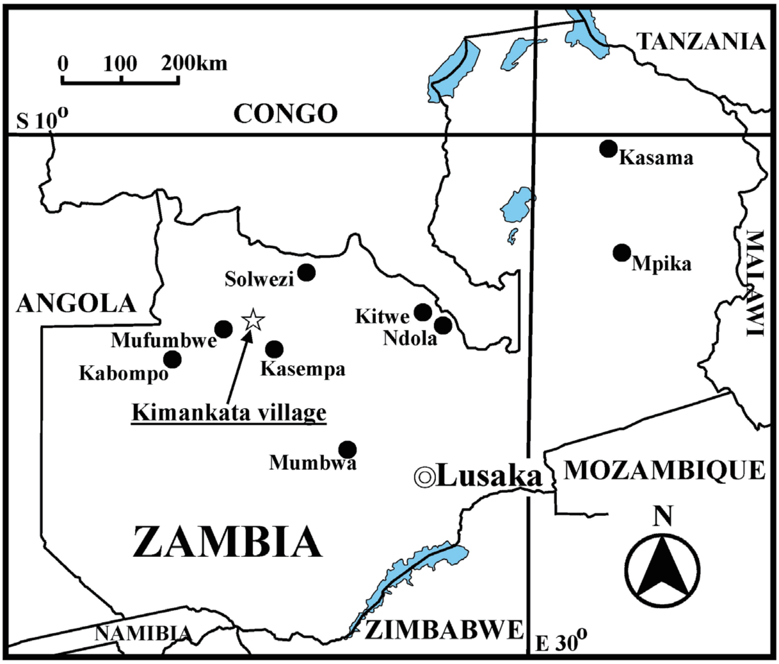

Fig. 1. Location of Kimankata village

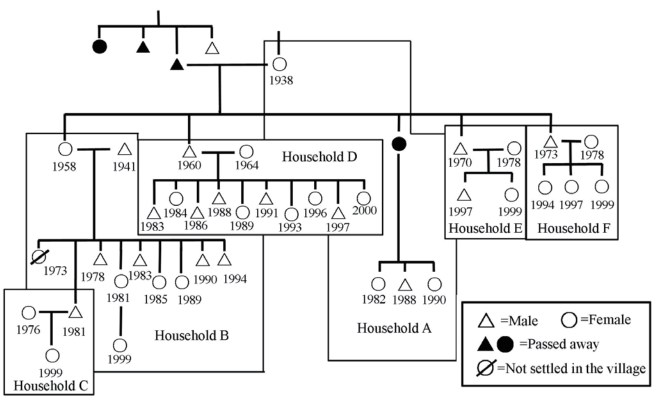

Fig. 2. Kinship relation of Kimankata Village (2001)

According to a population census performed by the Zambian government in 2000, the population of Kikonge Ward was approximately 1,900. The population of Kimankata Village was 38, with 6 households(1) (Fig. 2), each of which had a separate hut. The village name, Kimankata, derives from the name of a late husband of household A. He passed away in 1996, and the current headman was his first son, a male of household D. Although Kaonde society is matrilineal, the husband settles in his village. After marriage, males engage in bride service and work for the wife's parents at their field. The husband usually chooses to return his village after staying at his wife's village for 6 months.

The core member of Kimankata Village was a female of household A who was born in 1938. Her three sons and one daughter were living with her in the village. The village was an independent unit from an economic perspective. The linkage between households within the village was strong. Subsistence activity was based on mainly slash-and-burn cultivation called *bujimi*, as well as hunting, fishing, and gathering wild plants, mushrooms, and honey. Although each household cultivated and managed their own field, all the households within the village cooperated in agricultural activities. They also frequently shared their harvests. *Kupana* (generosity) was regarded as important for peaceful life in the village. They hated stingy (*kutana*) and selfish (*kuitemwa*) behavior in the villagers, which tended to cause troubles between them. Within the village, there was a regulation for sharing all food with all village members; in the words of the headman, "When we eat, all members eat. And in the case of food shortage, we all suffer from hunger." They said that the ideal village size is around four to six households. According to interviews, seven households was the maximum for living together in one village. When there were more than eight households within a village, villagers thought that some individuals tended to become selfish and stingy, resulting in quarrels and troubles.

The village was located between the *dambo* of Kasemetete and Jibompo in 2001 (Fig. 3). The settlement of six huts was surrounded by *bujimi* fields. The village had often moved settlements to seek suitable forest for slash-and-burn cultivation. Also, the deaths of major members caused the shifting of settle-

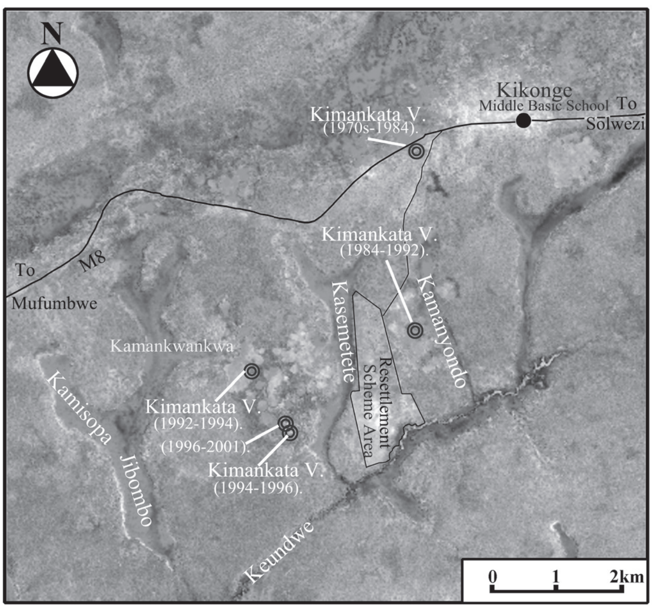

Fig. 3. Shifting settlement of Kimankata Village from 1984 to 2001 (Landsat TM image [path 174, row 69; November 5, 1994])

ments. After 1984, Kimankata Village moved four times (Fig. 3). The village site was located at the roadside in 1984 and was shifted to a new place near Kamanyondo *dambo* in 1984. The villagers estimated that the soil there was fertile and good for cultivating sorghum. A long-term stay at one site caused a decrease in the resource-rich forest around the settlement. The village moved again in 1992 to Kamankwankwa *dambo* for access to suitable woodland and better water resources because Kamanyondo is a small *dambo* and the water dried up during the dry season. Although suitable forest still remained around the settlement, the settlement was shifted in 1994. The former headman, Mr. Kimankata, died in 1996, and the place was considered to have an ill omen for causing the death of an important person. After the funeral, the villagers shifted to a new site located 100 m northwest of the old site to avoid continued misfortune (Fig. 3).

In the case of shifting settlements due to the loss of suitable forest, village members did not always move together, and each household decided to move in accordance with the end of the cultivation period of their fields. In the case of the death of a major adult member, the village site was considered to bring misfortune, and all members decided to move to a new settlement together after the funeral. When they moved to a new settlement, some members separated from the village. Through these resettlements, the number of households was maintained below seven.

BUJIMI SYSTEM: SLASH-AND-BURN CULTIVATION

The Kaonde people used the block *citemene* system for cultivation, which was called "*bujimi*" in the Kaonde language. *Bujimi* originates from *kujima*, which means "to cultivate." This is in contrast to the "*citemene*" of the Bemba, which is derived from kutema meaning "to cut trees."

The cutting of trees to open *bujimi* fields was the job of males, who cleared forest for 2 months from May to July (Fig. 4). They cleared new areas of closed forest every 3 or 4 years. They cut down all trees, except thorn trees and hard timber trees. Men piled up the leafy branches; these piles appeared to be rectangular in shape, resulting in the academic term "block *citemene*." Before they were set on fire, the future ash patches were called *bisanshi* (singular, *kisanshi*), and the input material of branches and stems was called *mwandalo* (singular, *myondalo*). The most area comprising both ash patches and cleared area was used for crop production. The villagers gradually expanded small plots of different field types in the newly generated grassland over several years. The area of *bujimi* fields varied from 0.5 to 1.5 ha, averaging 0.8 ha. The ash patches varied from 0.1 to 0.4 ha.

Villagers thought that cultivating the land was important for food production, but they also paid attention to the conditions of setting the fire. They recognized that crop yields were associated with fire conditions. Crop yields tended to be lower in fields where bush fire occurred before September and where the

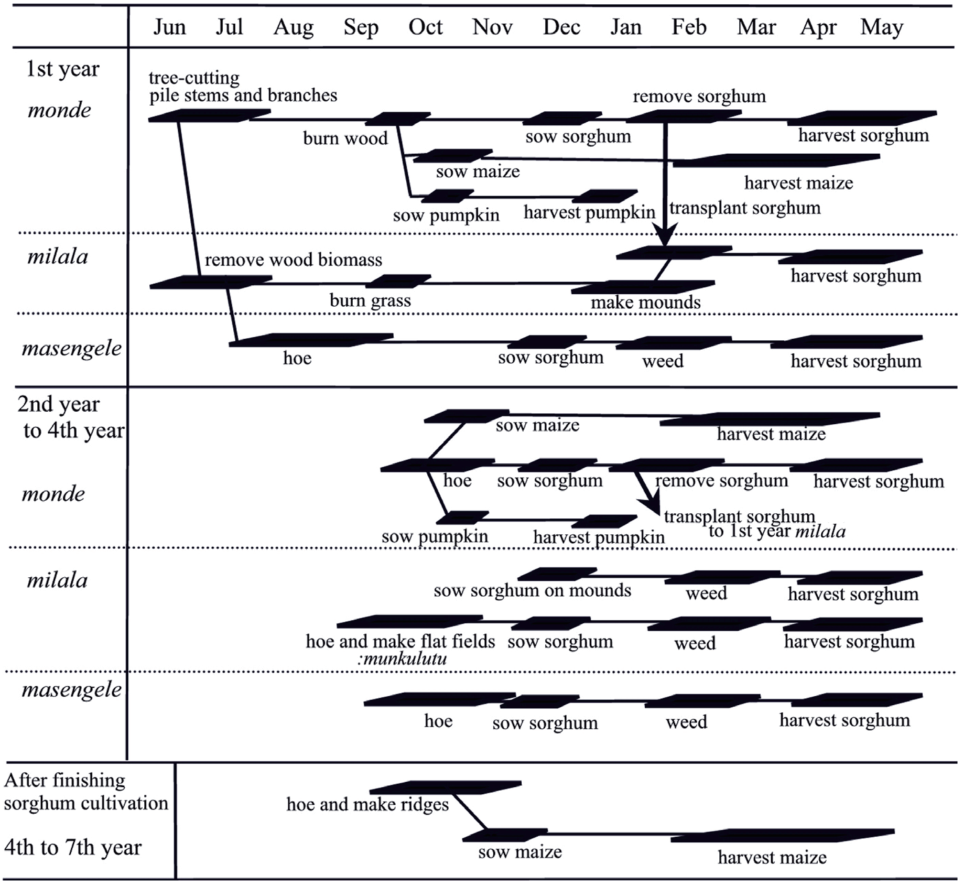

Fig. 4. Agricultural calendar of *bujimi* system

fire was incomplete. As soon as a man became aware of smoke in the direction of his new field, he hurried to the field. When there was danger of accidental fire spreading to the fields, villagers cut fresh branches and extinguished the fire by swatting it with the branches.

Villagers set fires in the *bujimi* in mid-October, usually several times to burn it completely. They called first fire "*kimekitanshi mwasoka*." If they judged that a burn was incomplete, they gathered the burnt stems and set the fire again. The second fire was called "*bikuka*."

Sorghum(2) was sown for three or four consecutive years. Villagers usually opened new *bujimi* fields at 3- or 4-year intervals (Fig. 5). After sorghum cultivation, villagers usually planted maize continuously for additional 3 or 4 years. It was common for each household to manage one sorghum field and one maize field.

The first year's fields were called "*bujimi bwa mujilo*" (field of fire). Within the *bujimi* fields, there were three types of cropping systems: *monde*, or ash patches; *masengele*, or flat fields; and *milala*, or mound cultivation. The whole

Household	1994	1995	1996	1997	1998	1999	2000	2001
A	○		D		○		○	
B		○				○*		○
C			○			○*		
D						M	○	
E			M				○	
F	M		○		○			

Fig. 5. Agricultural season of opening a new *bujimi* field in Kimankata village
M: marriage, D: death of husband in household A
* Household C received a *bujimi* field from household B

area was sown with sorghum.

Ash patches were called *monde* (singular, *myonde*). They were created by the complete burning of the wood biomass. Burning at the soil created soft soil conditions and good soil fertility called *fuka* or *kajo*. Ash was called *buto*. Villagers looked at the color of the ash to judge the burning conditions. Black ash on the ground indicated insufficient burning, whereas white ash was a sign of suitable burning for sorghum cultivation. In the case of insufficient burning, the villagers hoed and mixed the black ash with the surface soil to improve soil conditions. Villagers rarely hoed in the favored white ash patches because they estimated that the soil was soft enough. *Monde* was considered suitable for the planting of sorghum, maize, pumpkin, and edible gourds (Table 1). Villagers sowed maize from the end of November to mid-December and sowed sorghum in mid-December (Fig. 4). They sowed sorghum more densely in *monde* from January to March for transplantation to other parts of the field, especially the *milala*.

Table 1. Suitability of crops in the three cropping systems

English name	Sciencific name	Kaonde name	*Monde*	*Masengele*	*Milala*
Sorghum	*Sorghum bicolor*	*Mebele*	◎	○	○
Maize	*Zea mays*	*Mataba*	◎	○	○
Finger millet	*Eleusine coracana*	*Luku*	○	X	X
Cassava	*Manihot esculenta*	*Makamba*	X	X	◎
Groundnuts	*Arachis hypogaea*	*Nyemu*	X	◎	◎
Pumpkin	*Cucurbita moschata*	*Myungu*	◎	X	X
Sweet potato	*Ipomoea batatas*	*Ntamba*	X	X	◎
Watermelon	*Citrullus vulgaris*	*Inamunwa*	◎	X	X
Cucumber	*Cucumis sativus*	*Bibimbi*	◎	X	X
Gourd	*Crescentia cujote*	*Bituwa*	◎	X	X
Beans	*Phaseolus vulgaris*	*Nkunde*	X	○	○
Cowpea	*Vigna unguiculata*	*Lwanda*	○	○	○
Yam	*Dioscorea dumetorum*	*Kilungwa*	X	X	○
Okra	*Hibiscus esculenta*	*Okura*	◎	X	○
Leafy vegetables	*Erucastrum arabicum*	*Cibangankonde*	○	○	○
Fish poison	*Tephrosia vogelii*	*Buba*	◎	○	○
Tobacco	*Nicotiana tabacum*	*Fwaka*	○	○	○

◎: very suitable, ○: suitable, X: not suitable

Villagers also planted sorghum in unburned land, and the fields were divided into two local terms depending on the cultivation season. Fields ploughed in the dry season were called *masengele* (singular, *nsengele*), whereas those ploughed in the rainy season were called *milala* (singular, *malala*).

Masengele are flat fields. Villagers lightly hoed the surface soil layers to 10 cm in depth and mixed this with grass biomass during the dry season from May to September. They did not make ridges or mounds before sowing sorghum. Although villagers estimated that the soil fertility was low, they cultivated *masengele* to reduce agricultural work during the rainy season. After constant rain in mid-November, they sowed sorghum from December to early January.

Milala are mound cultivations. When villagers burned the wood biomass in *monde*, they also set fire to the grass in the rest of the field. After burning the grass in October, re-growth started quickly. Grass stems reached 60 cm in height by the end December. Villagers started making *milala* by concentrating grass biomass and surface soil beginning at the end of November, overturning surface soil with grass roots and gathering surface soil from the surroundings. The diameter of the mounds was approximately 2 m and their height was 50 cm. After making mounds, villagers transplanted sorghum from *monde*. They cut the leaves of the transplanted sorghum by hand, 20 cm from the top of leaves, because the sorghum became dry soon after transplanting if the leaves were not cut. This activity continued until the second week of March, when the rains had nearly ended.

Villagers harvested pumpkin beginning in January and maize beginning in late February. In all field types, villagers harvested sorghum from May to July (Fig. 4). Sorghum was especially vulnerable to birds and baboons, and all family members helped scare animals away from the ripening crops. Before finishing the harvest, villagers usually stayed in a watch hut built on an anthill and beat wooden materials to scare away animals.

The fields after the second year were called *mukiputu*. This name did not change until the fields were abandoned. In mid-October, villagers collected the sorghum and maize residue and set fire to it, away from the sites of the previous year's crops. They hoed lightly in *monde* and *masengele*, but not in *milala*, before sowing crops. When villagers noticed a decline in soil fertility in third- or fourth-year *milala* fields, the mounds were knocked down and soil was mixed with the rotting grass biomass. According to the villagers' explanation, they made flat fields to create new soil. This type of flat field was called *munkulutu*.

Although the agricultural jobs in the second- and third-year fields were the same as in the first-year fields, more weeding was required. After the second year, many weed species grew in the fields. Villagers noted the types and amounts of weeds. They carefully removed one type of weed, *Stringa asiatica* (*kalumba*); this weed dramatically reduced soil fertility and crop yields. In second-year fields, *mukiputu*, villagers reaped sorghum from May to July.

The village households cooperated in the major agricultural works such as cultivating, weeding, scaring away animals, and harvesting. All village members collaborated in cultivating *masengele* during the dry season, *munkulutu* immediately before the rainy season, and *milala* during the rainy season. Sorghum and maize were the major food staples for the Kaonde people. They used these crops for cooking *nshima*, a corn starch meal. They preferred sorghum to maize and cassava as the basis of *nshima*.

All households monitored crop yields and weed types, and they decided jointly on creating new fields at different places. They usually cleared forest and opened new *bujimi* fields every 3 or 4 years. After cultivating sorghum, villagers planted maize for additional three to four consecutive years. They concentrated the topsoil and made ridges with hoes. Villagers used maize not only as a staple food, but also for cash income. A small-scale merchant came to the village from April to September. The merchant bought maize from villagers in exchange for *salaula* (used-cloth), *citenge* (new cloth for women), salt, cooking oil, bicycle parts, and other items.

SPATIAL STRUCTURE OF *BUJIMI* FIELDS AND CROPS

I. Inner Structure of *Bujimi* Fields

I used a hand compass and set a baseline from north to south in the *bujimi* fields of households A and F. Every 5 m along this baseline, lines were set from east to west, and the type of cropping system, the planted crops, and the year the field was created were recorded at points every 5 m along the lines.

The *bujimi* fields of household F (Fig. 6) and household A (Fig. 7) showed not only various cropping systems (*monde*, *masengele*, and *milala*), but also variation in the number of years they had been cultivated. Household F opened a new *bujimi* field in 1998 and expanded three cropping systems for three agricultural seasons in 1998, 2000, and 2001. In 1999, they made only *milala*. Household A opened a new *bujimi* field in 2000 and expanded *monde*, *masengele*, and *milala* in 2000 and 2001. The interiors of the *bujimi* fields could be classified into seven types in household F and four types in household A, depending on the cropping systems and number of years cultivated.

When household F cleared 94.00 ares of forest (Table 2) in 1998, the husband cut trees and piled branches for *monde* from June to July. He also assisted his wife in cultivating the flat *masengele* fields from June to September. After finishing cultivation in the *masengele*, he set fire to the piled branches and made *monde* ash patches. They sowed maize in November and sorghum in December. They cut grass and buried it into *milala* from January to March; at the same time, they transplanted sorghum stands from *monde* to *milala*. In the 1998 season, the cultivated area was 29.50 ares of *monde*, 22.00 ares of *milala*, and 13.75 ares of *masengele* (Table 2). The location of the three cropping systems was irregular and formed a mosaic pattern (Fig. 6). The husband esti-

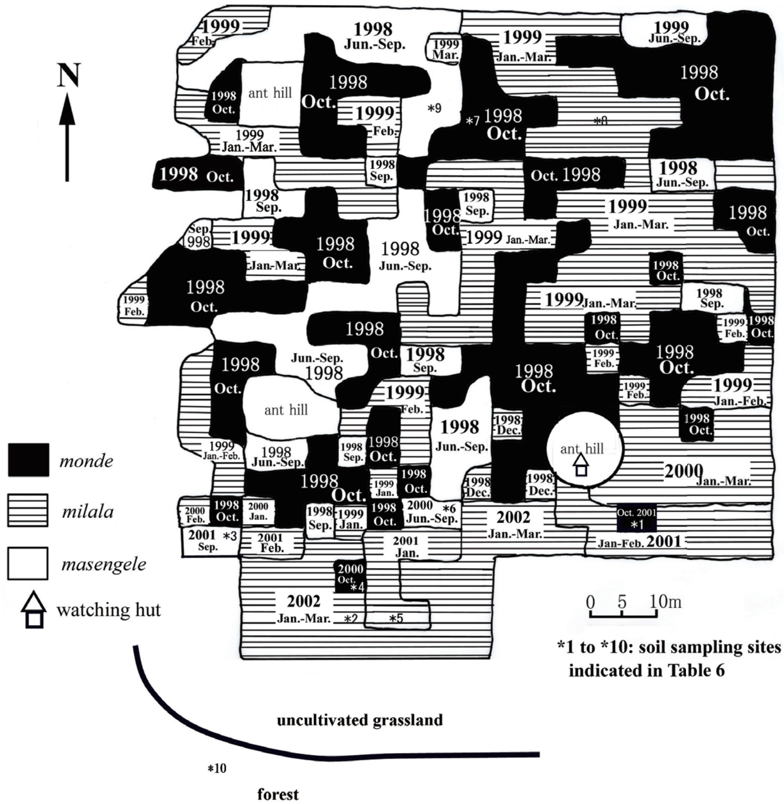

Fig. 6. *Bujimi* field map of household F: cropping system and cultivated year

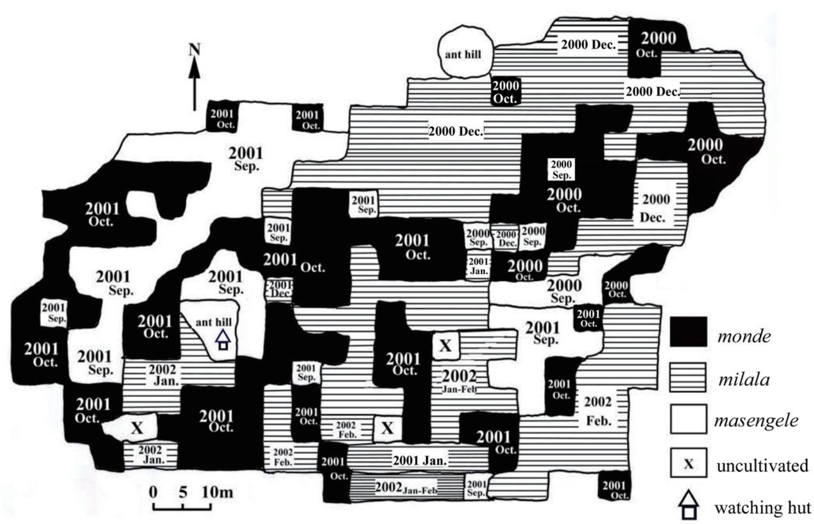

Fig. 7. *Bujimi* field map of household A: cropping system and cultivated year

Table 2. Newly cultivated area in *bujimi* field of household F

	1998	1999	2000	2001	Total	
Cleared forest (are)	94.00		14.00		108.00	
Cultivated area (are)						
Monde	29.50	0	0.25	0.25	30.00	(34.4%)
Milala	22.00	4.50	5.00	11.00	42.50	(48.7%)
Masengele	13.75	0	0.50	0.50	14.75	(16.9%)
Total	65.25	4.50	5.75	11.75	87.25	(100%)

mated that the soil was fertile in this field. The crop yields were very suitable in 1998 and they expected good yields the next year. They expanded only 4.50 ares of *milala* in 1999. The husband noticed a decline in the sorghum crop in 2000 and cultivated new *milala* in the neighboring grassland. This *Hyparrhenia mutica* grassland was cleared in 1998 and left fallow for 2 years. During the rainy season, they concentrated grass biomass and surface soil to make *milala*. Trees regenerated in some places. The husband cut down these small trees and piled wood at one place to open a small *monde*. They cut down trees and expanded a new plot of 14.00 ares. The newly cultivated area in the 2000 season was 0.25 ares of *monde*, 5.00 ares of *milala*, and 0.50 ares of *masengele*. In the 2001 agricultural season, they opened additional 0.25 ares of *monde*, 11.00 ares of *milala*, and 0.50 ares of *masengele*. The total cultivated area of Household F was 87.25 ares, including 30.00 ares (34.4%) of *monde*, 42.50 ares (48.7%) of *milala*, and 14.75 ares (16.9%) of *masengele*. They tended to open *monde* the first year after clearing forest, and *milala* the second and third years. Household F planned to open a new *bujimi* field at another place in the 2002 season. Although some parts of fields were cultivated for three to four consecutive years, some portions were cultivated for a shorter time.

Household A opened a new *bujimi* field in the 2000 agricultural season. The second son (a male from household E) and the third son (a male from household F) helped clear 97.00 ares of forest for their mother (Table 3). The mother cultivated *masengele* in September 2000. The family set fires and made *monde*

Table 3. Newly cultivated area in *bujimi* field of household A (are)

	2000	2001	Total	
Cleared forest (are)	97.00		97.00	
Cultivated area (are)				
Monde	4.50	21.75	26.25	(35.5%)
Milala	17.00	16.00	33.00	(44.6%)
Masengele	2.00	12.75	14.75	(19.9%)
Total	23.50	50.50	74.00	(100%)

in October. In December, all adult members of the village engaged in cultivating *milala* for one day (Fig. 7). The newly cultivated area was 4.50 ares of *monde*, 17.00 ares of *milala*, and 2.00 ares of *masengele* (Table 3). The mother estimated that the soil in the *bujimi* fields was sandy and not fertile enough. In this year, she was not satisfied with the sorghum production and felt it was necessary to expand the fields. In the 2001 agricultural season, the family opened new *monde*, *milala*, and *masengele* fields. The newly cultivated area was 21.75 ares of *monde*, 16.00 ares of *milala*, and 12.75 ares of *masengele*. She planned to cultivate the *bujimi* field for another year, the 2002 season. The total *bujimi* area was 74.00 ares in February 2002, including 26.25 ares (35.5%) of *monde*, 33.00 ares (44.6%) of *milala*, and 14.75 ares (19.9%) of *masengele*.

The family thought it was important to expand new fields every year, even if the expansion was small. This effort was associated with not only expanding the cultivated area for higher yield, but also creating fresh soil within the *bujimi* fields. According to interviews with villagers, the yield of *monde* was suitable in first-year fields, although crop production declined as the cultivation period progressed. Although sorghum yields were low in the first year of *milala* and *masengele*, crop yields improved in the second and third years.

II. *Bujimi* Field Crops

There were 13 major crops planted in *bujimi* fields (Table 1). In the fields of

Table 4. Cultivated crops on the three cropping systems in *bujimi* of household F (February, 2002)

Agricultural season of the opened fields	1998			1999			2000			2001			Total
	Monde	*Milala*	*Masengele*	*Monde*	*Milala*	*Masengele*	*Monde*	*Milala*	*Masengele*	*Monde*	*Milala*	*Masengele*	
Total plot number [a]	118	88	55	0	18	0	1	20	2	1	44	2	349
Cultivated area (are)	29.50	22.00	13.75	0	4.50	0	0.25	5.00	0.50	0.25	11.00	0.50	87.25
Sorghum	118(100[b])	88(100)	55(100)		18(100)		1(100)	20(100)	2(100)	1(100)	44(100)	2(100)	349(100)
Finger millet													0(0)
Maize	66(56)	60(68)	16(29)		7(39)		1(100)	10(50)		1(100)	14(32)		175(50)
Cassava	1 (1)	3(3)			1(6)						2(5)		7(2)
Sweet potato	25(21)	23(32)	7(13)		6(33)			13(65)			10(23)		84(24)
Pumpkin	24(20)	12(14)	1(2)		4(22)			1(5)			3(7)		45(24)
Cucumber	1(1)	1(1)											2(1)
Cowpea	25(21)	7(8)			1(6)								33(9)
Fish Poison	18(15)	12(14)	2(4)		2(11)						1(2)		35(10)
Tomato	1(1)	1(1)											2(1)
Okra	5(4)	4(5)	1(2)										10(3)

a) size of plot is 5m × 5m quadrate
b) counting the number of plots where they cultivated the crop and calculating the percentage of the cultivated plots to the total number of the plots

household F, sorghum was observed in all plots (Table 4). The density of sorghum was 9–18 stands per m^2 of *monde*, 3–8 stands per m^2 of *milala*, and 6–13 stands per m^2 of *masengele*. Maize was cultivated in 50% of *bujimi* fields, mainly on *monde* and *milala*. The family carried out mixed cropping of several crops such as sorghum, maize, sweet potato, pumpkin, cowpea, fish poison (*Tephrosia vogelii*), tomato, and okra in *monde* and *milala*. In *masengele*, sorghum monoculture was common. *Monde* provided an important crop, pumpkin, during the sorghum off season. The family said, "Without *monde*, it is difficult for us to obtain food during the off-crop season of sorghum from January to March." They harvested pumpkin and used it from late January to mid-February. They also used fresh maize for cooking *nshima* beginning in mid-February.

In the *bujimi* field of household A, sorghum was planted in all parts of the cultivated fields (Table 5). In the 2000 season, the mother planted sorghum, maize, pumpkin, and cowpea in *monde*. In *milala* and *masengele*, only sorghum and maize were grown with mixed planting. In second-year fields, the mother carried out mixed cropping of sorghum, maize, and pumpkin in *monde*, sorghum with sweet potato in *milala*, and a monoculture of sorghum in *masengele*. The Kaonde people recognized that sorghum was their staple food for subsistence and the *bujimi* fields were places of sorghum production. They cultivated pumpkin and maize as early-maturing crops to supplement their diet because sorghum is out of season from January to March, just before the harvest season.

Table 5. Cultivated crops on the three cropping systems in *bujimi* of household A (February, 2002)

Agricultural season	2000			2001			Total
	Monde	*Milala*	*Masengele*	*Monde*	*Milala*	*Masengele*	
Total plot number [a)]	18	68	8	87	64	51	296
Estimated area (are)	4.50	17.00	2.00	21.75	16.00	12.75	74.00
Sorghum	18(100%)	68(100%)	8(100%)	82(94%)	50(78%)	51(100%)	277(94%)
Finger millet	2(11%)						2(1%)
Maize	16(89%)	67(99%)	7(88%)	37(43%)	30(47%)	9(18%)	166(56%)
Cassava	1(6%)				15(23%)	1(2%)	17(6%)
Sweet Potato							0(0%)
Pumpkin	12(67%)	33(49%)		34(39%)	8(13%)	3(6%)	90(30%)
Cucumber							0(0%)
Cowpea	9(50%)	20(29%)	2(25%)	1(1%)	40(63%)		72(24%)
Fish Poison			1(13%)	1(1%)			2(1%)
Tomato							0(0%)
Okra							0(0%)
Under cultivation				5(6%)	10(16%)		15(5 %)

a) size of plot is 5m × 5m quadrate

CROPPING SYSTEM AND SOIL FERTILITY

I. Soil Sampling and Analysis

Nine sites were selected for soil sampling in one *bujimi* field of household F (Fig. 6). Soil samples were collected from soil layers 0–10, 10–20, and 30–40 cm deep. The roots of sorghum were 15–20 cm deep. All samples collected for chemical analysis were air-dried in the research village, placed in polythene bags, and transported by air to Japan. The soil samples were passed through a 2 mm mesh sieve. The pH and total N, total C, exchangeable K, Ca, and Mg, and available P contents were measured. Soil pH was determined in water or KCl at a ratio of 1:5 using a glass electrode (Ion Meter N-8F, Horiba Ltd., Japan). Total N and total C contents were measured using a NC analyzer (Gas Chromatograph GC-8A, Sumigraph NC-90A, Shimadzu Co., Japan). Exchangeable K was measured using flame photometry (Atomic Absorption Spectrophotometer AA-670G, Shimadzu Co., Japan). The exchangeable Ca and Mg contents were measured using induced coupled plasma spectrophotometry (IRIS advantage, Nippon Jarrel Ash Co., USA). The P content was measured colorimetrically (UV-2500PC, Shimadzu Co., Japan) after extraction by the Bray No. 2 method.

II. Soil Fertility of *Bujimi* Fields

For the soil chemical properties of the *bujimi* fields, including the three cropping systems and the neighboring forest, the pH, exchangeable K and Ca, available P, total N, and total C in the surface soil 0–10 cm deep were much higher in the first-year *monde* than in the forest soil (Table 6). This may have been caused by burning and the addition of ashes and charcoal. However, fire did not affect strongly soil layers deeper than 10 cm. Soil nutrients in the *monde* decreased after 2 to 4 years of cultivation.

To cultivate *milala*, villagers accumulated the surface soil into mounds. In first-year *milala*, there was more exchangeable K, Ca, and Mg, total N, and total C in soil layers 10–20 cm deep than in soil layers 0–10 cm deep (Table 6). It was notable that despite continuous cultivation, the soil nutrients of the 10-20 cm soil layer in the second year were as high as those of first-year *milala*. This indicates that organic matter incorporated into the sub-soils gradually decomposed and released nutrients.

In *masengele*, soil nutrients accumulated in the 0–10 cm soil layer, which was hoed lightly (Table 6). Some nutrients (e.g., Mg and Ca) increased after 2 years of cultivation. After 4 years of cultivation, the nutrient content did not decrease dramatically. Preservation of soil fertility could be associated with the buried grass biomass in the soil.

The amount and mode of soil fertility preservation differed among the three cropping systems. The increase in soil nutrients was limited to the 0–10 cm soil layer in *monde* and *masengele*, whereas *milala* accumulated soil fertility at depths of 10–20 cm. Soil fertility dynamics differed among the three cropping systems based on the length of cultivation. Soil nutrients decreased gradually in *monde* after cultivation due to run-off and plant uptake. Soil nutrients in *milala* and *masengele* in the second year were as high as those in the first year, even under cultivation, because gradually decomposed grass biomass was incorporated into the sub-soils.

Table 6. Soil chemical property of *bujimi* fields in household F (February, 2002)

	Location No.[a]	pH		Exch. Base (cmol(+)/kg)			Total		C/N	P (ppm)
		H_2O[b]	KCl[b]	K^+	Mg^{2+}	Ca^{2+}	N	C (%)		
1st year after cultivating										
Monde	*1									
0- 10 cm		7.43	7.13	0.62	3.65	22.86	0.27	4.19	15.4	133
10- 20 cm		6.36	4.43	0.08	1.36	1.75	0.11	1.28	12.1	4
30- 40 cm		6.09	4.29	0.05	0.57	0.73	0.08	0.84	11.1	2
Milala	*2									
0- 10 cm		6.30	4.71	0.10	0.60	1.66	0.08	0.98	13.0	9
10- 20 cm		6.28	5.18	0.27	0.94	2.49	0.10	1.30	13.1	15
30- 40 cm		5.83	4.37	0.02	0.40	0.69	0.05	0.46	9.9	7
Masengele	*3									
0- 10cm		6.88	6.23	0.41	0.79	2.27	0.12	1.70	14.2	26
10- 20 cm		5.61	4.25	0.22	0.45	1.06	0.06	0.88	14.7	4
30- 40 cm		5.46	4.19	0.05	0.45	1.35	0.04	0.55	13.8	2
2nd year after cultivating										
Monde	*4									
0- 10 cm		7.64	7.28	0.52	1.22	13.27	0.16	2.26	14.3	116
10- 20 cm		7.20	5.29	0.13	2.39	1.89	0.11	1.40	13.4	9
30- 40 cm		5.84	4.41	0.07	0.80	0.77	0.06	0.69	12.5	9
Milala	*5									
0- 10 cm		6.55	5.11	0.25	1.63	5.45	0.16	2.35	14.5	26
10- 20 cm		6.22	5.01	0.48	2.68	5.11	0.23	3.23	14.0	21
30- 40 cm		5.74	4.22	0.13	1.17	1.36	0.07	0.91	12.3	4
Masengele	*6									
0- 10 cm		6.56	5.57	0.38	2.34	6.02	0.18	2.54	14.3	43
10- 20 cm		6.22	4.52	0.15	1.53	1.25	0.09	1.26	13.3	7
30- 40 cm		5.68	4.35	0.07	1.39	0.70	0.07	0.78	11.6	4
4th year after cultivating										
Monde	*7									
0- 10 cm		8.23	7.62	0.78	1.26	13.47	0.14	1.76	12.9	109
10- 20 cm		6.31	4.82	0.12	0.78	1.97	0.08	1.01	12.0	11
30- 40 cm		5.85	4.47	0.07	1.17	0.72	0.06	0.59	9.8	4
Milala	*8									
0- 10 cm		6.44	4.99	0.33	1.34	3.49	0.14	1.88	13.9	13
10- 20 cm		5.70	4.34	0.08	0.82	1.33	0.08	1.00	12.2	7
30- 40 cm		5.29	4.23	0.04	0.71	0.42	0.04	0.37	9.0	4
Masengele	*9									
0- 10 cm		6.95	6.03	0.31	1.57	8.64	0.18	2.53	14.0	37
10- 20 cm		5.64	4.37	0.21	0.82	0.63	0.07	0.72	11.1	7
30- 40 cm		5.19	4.28	0.14	0.58	0.41	0.05	0.43	9.7	4
Forest soil	*10									
0- 10 cm		6.09	4.95	0.07	1.28	2.47	0.14	1.79	13.1	6
10- 20 cm		5.91	4.50	0.03	0.39	0.83	0.08	1.05	13.2	15
30- 40 cm		6.28	4.45	0.01	0.29	0.48	0.06	0.70	11.6	4

a) The location of soil sampling in *bujimi* field is indicated in Fig. 6.
b) soil: water or IN-KCl=1:5.

DISCUSSION

I. Complex Cropping Systems in *Bujimi* Fields

Recent studies have examined crop diversification in tropical cultivation areas. Mixed cropping, or multiple cropping systems with several crops, is an adaptive strategy to avoid declining crop yields with pest, disease, and weed control in unstable tropical environments (Edje, 1982; Nadar, 1982; Altieri & Liebman, 1986). This technique increases production per land unit, diversifies labor hours, and adapts to climate variability, and also avoids the negative impacts of pests and diseases. The Kaonde people regard mixed cropping as more important for soil fertility diversification rather than crop diversification in the *bujimi* system.

The diversification of soil conditions in *bujimi* fields was due to the cropping system, the number of years the soil was cultivated, and the soil fertility dynamics. *Bujimi* cultivation comprised three cropping systems: *monde*, making ash patches; *milala*, making mounds; and *masengele*, making flat fields. The locations of the three cropping systems were irregular, resulting in a mosaic pattern. Depending on the characteristics of the three cropping systems, soil nutrients accumulated in different soil layers. In *monde*, ash provided a large amount of important nutrients such as available P and K, up to 10 cm deep. *Masengele* contained fertile surface soil with grass biomass as green manure, and soil fertility was concentrated in the 0–10 cm soil layer. *Milala* concentrated soil fertility in the mound, mixed with grass biomass and fertile surface soil. Soil nutrients were found in soil layers up to 20 cm deep.

These cropping systems provided different types, quantities, and depths of accumulated soil nutrients, and also different types of crop environments such as weed control and soil moisture. In *monde*, the burning of woody biomass controlled weed growth. *Milala* protected soil from erosion and nutrient run-off, as Stromgaard (1990) reported for mound cultivation by the Mambwe people in northeastern Zambia. *Milala* maintained soil moisture and controlled weed growth by enclosing grass biomass in the mounds. *Milala* was well drained in the wet season from December to February and the soil moisture level was also maintained from mid-March to April when the rains were ending. Therefore, the villagers could transplant sorghum stands from *monde* to *milala* until mid-March.

Soil fertility dynamics were diverse among the three cropping systems. The soil nutrients in *monde* gradually decreased after burning because of run-off and crop uptake. The *monde* soil continued to become exhausted, and crop yield also tended to decrease after 3 or 4 years of cultivation. In contrast, soil fertility in *milala* and *masengele* were preserved after 2 years of cultivation. The *milala* and *masengele* fields were suitable for 3 or 4 years of continuous sorghum cultivation, although sorghum yields during the first year on *milala* and *masengele* were not better than on *monde*.

The villagers gradually expanded small plots in the grassland of the cleared forest every year for three or four consecutive years. This activity maintained the sorghum yield for household food supplies. There were six or nine types of fields existing within one *bujimi* field, classified by the cropping system and the number of years cultivated. Based on simple calculations, 4 years of continuous cultivation enabled a maximum 12 types of fields.

Itani (2002) focused on the vegetation type and soil fertility of the farming systems in East Africa and classified two types of farming system: burning type and rotting type. According to this classification, the *bujimi* system comprised both the burning type (*monde*) and the rotting type (*milala* and *masengele*). The soil fertility of *monde* depended on wood biomass, and that of *masengele* and *milala* depended on the mixing of grass biomass with surface soil. In selecting a new site for a *bujimi* field, wood biomass was critical for making *monde*, and the Kaonde cultivators selected woodlands dominated by trees such as *Brachystegia*, *Isoberlinia*, *Acacia*, and *Pterocarpus*. They also carefully observed the grass species and amounts of grass biomass in the woodland. They looked for *Hyparrhenia mutica* (*kibabe*) and preferred vigorous grassland of this species as forest for clearing. After cutting the trees, the villagers left some open land uncultivated to produce vigorous *H. mutica* grassland. On the uncultivated land, light conditions improved and grass biomass increased rapidly. The ground was soon covered with *H. mutica*, which protected against soil erosion. Simultaneously, some chemical properties of the topsoil improved, such as exchangeable K and Ca and available P (Oyama, 2007). The villagers used the grass biomass and improved the topsoil, concentrating the biomass into *milala* mounds for sorghum cultivation.

According to interviews with the villagers, they could cultivate sorghum by making *masengele* and *milala* after clearing the uncultivated *H. mutica* grassland. However, they did not currently intend to open a *bujimi* field in the grassland (in 2005) for two reasons. First, heavy labor is necessary for cultivating *milala* from grassland, and they needed to open *monde* to disperse labor hours from the rainy season to the dry season. Second, they regarded pumpkin and edible gourds as important crops that can be harvested only in *monde*. These crops provide necessary food during the off-crop season. The villagers combined the three cropping systems for food production and dispersed the labor between the rainy season to the dry season.

II. Soil Fertility Dynamics and Mixed Cropping

The agro-space diversification could be divided into two types: cultivators opened several fields depending on natural variation and seasonal changes, and they made variations within a field. Academic interest in the diversification of a field has been concentrated on the biological aspects of the crop species, especially for mixed cropping techniques (e.g., Francis, 1986). The mixed cropping technique means that various plant species and crop varieties are planted in a field, stabilizing crop yields, dispersing labor hours, coping with rainfall variability, and controlling pests and diseases.

The *bujimi* field was not strongly related to the biological aspects of crop diversification, but rather to the soil conditions created by the cropping systems, the soil fertility dynamics, and the time-lag in cultivation after clearing. The three cropping systems differed in the type and amount of soil nutrients, as well as the depths at which soil fertility was accumulated. This diversification of soil fertility in the *bujimi* fields also helped cope with rainfall variability.

Simultaneously, the soil fertility dynamics varied with the cropping system. Soil nutrients in *monde* gradually decreased after cultivation because of crop growth and run-off. In contrast, those in *milala* and *masengele* remained high for 2 years after clearing the forest, even under cultivation. When the Kaonde people judged a loss in soil fertility and resulting crop failure, they sowed maize and pumpkin more densely in *monde* and planted sweet potato and cassava in *milala* in the middle of the rainy season. These supplementary crops are important for food sustainability. Crop diversification tended to increase in the exhausted soil conditions of the fields. The Kaonde people generated various soil types to cultivate sorghum in the three cropping systems and simultaneously used mixed cropping to counter-balance soil fertility loss. The diversification of soil conditions and crops within a *bujimi* field avoided concentrating labor hours during specific seasons and stabilized food production by coping with the rainfall fluctuations, as well as controlling pests and diseases.

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NOTES

(1) A household was regarded as a unit of consumption. All households within one village opened *bujimi* fields and usually cooperated in agricultural activities. The harvested crops were frequently shared among households within a village, but not outside the village.

(2) In the research village, five varieties of sorghum were identified by the villagers. These were *makombe*, *mukuba*, *matete*, *musengu*, and *kamuntu*. *Makombe* was highly valued for its white grain and better yield, although the villagers did not select the seed of specific varieties for planting.

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